EFFECTS OF SHIFTING CULTIVATION ON THE SOIL MESO-FAUNA WITH SPECIAL REFERENCE TO COLLEMBOLAN POPULATIONS IN THE NORTH-EAST THAILAND

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Summary

The effects of burning on soil fauna were estimated in terms of population density, vertical distribution, species composition and community structure.

In this study area, the microarthropods consisted of Acarina (82%), Collembola (7%), and others (11%). During the study period, the population density of Collembola was significantly higher in the forest area than in the shifting cultivation area, while such difference in numbers was not observed in Acari and the others. These results indicate the high sensitivity of Collembola. The decrease in numbers of Collembola was accounted for by the reduction of habitats after the burning. Population changes in Collembola and Acari were studied during the period, December 1979 to June 1980. Population densities of Collembola and Acari were low during the dry season. The pattern of seasonal changes in number of Collembola was similar in the two study area, i.e. the forest and shifting cultivation plots. The pattern of Acari in the shifting cultivation plot, however, was different because of the sudden increase of one species of Acari. The pattern of Acari in forest plot was similar as that of Collembola. So, except for the Acari in the shifting cultivation plots, the two groups had the same population peaks in April when the rainy season began.

Changes in community structure of Collembola were studied in both areas. The diversity of Collembola was low at the end of the dry season in March of 1980. Diversity was not noticeably different between the forest and shifting cultivation plots. Burning effects were reflected in species richness rather than the evenness component; this may suggest that the rare species were eliminated from the community by the burning practices.

Introduction

Shifting cultivation is a traditional agricultural practice in the tropical countries and usually refers to the practices of cutting trees and shrubs, burning, growing crops for one to about 5 years and then allowing a natural cover to return to regenerate the productivity of the soil (KELLOG 1963). An ecological knowledge of the environmental impact of this agricultural practice is important for the rational use of land. A co-operative research project has been developing to understand the ecological basis of shifting cultivation (KYUMA et al. 1980) and an ecological study of soil animals has took part within the framework of the research project.

Ecological studies of soil animals have been undertaken in the tropical countries, where much attention has been paid for the study of termites which are dominant animals in the tropical soils (LEE and WOOD 1971). There is, however, rather little information concerning the role and importance of soil microarthropods usually consisting of Collembola and Acari. In the temperate forest soils, Collembols and Acari are nummerically abundant and may contribute to the soil formation and litter decomposition. Comparative studies of soil microarthropods are necessary to evaluate the relative importance of this animal group in the tropical soil.

The objectives of this study are to determine the effects of shifting cultivation practices on the populations of soil microarthropods, the seasonal changes in number of Collembola and Acari and special attention has been paid for Collembolan populations.

Study Area

The study area of this experimental shifiing cultivation is situated at the Khon Kaen University Farm locating at about 140 km west of Khon Kaen in north-east Thailand. Topograph of the area is rolling to hilly. Description of this experimental area is already reported (KYUMA et al. 1980). Basing on the report, the conditions of this study area are summerized as follows.

Forest vegetation of the study area is the mixed dry deciduous forest (MDF type forest), consisting of deciduous trees, such as *Lagerstroemia spp.*, *Terminalia spp.*, *Darbergia chochinchinensis*, *Pterosperumum sp.*, and *Pterocarpus sp.*, mixing with evergreen trees. The crown height of this forest is about 20–25 meters.

The experimental plots for the study are located on both sides of a small valley at about 800 m in altitude and consists of three croping plots being each 40×40 m^2 in area and a forest plot of 40×40 m^2 in area as a control plot. The cropping plots were established by clearing and burning the forest vegetation. The clearing of trees and shrubs was carried out during the period from 20 to 22 December 1979. The felled trees and shrubs were left on the ground for drying until mid January 1980 and then burnt during 14 to 18 January 1980. In May 1980, maize was sowed in the cropping plots without tillage at the onset of the rainy season and growed up at about 1.5 m in height with flowering at the last sampling occasion in June 1980.

The basement rocks of the area are Mesozoic sands stones and siltstones with strongly redish coloration. The soil profile showed no well developed structure. The soil surface is covered with A_0 layer mainly consisting of litter layer. A layer is about 10 cm in thickness and the top part contained much organic matter. The effects of burning on soil profile depended upon the intensity of burning. The intensively burned places showed an accumulation of ash layer in patchy patterns. By the burning, the A_0 and top of A layer lost organic matter, so the soil surface was exposed to air. During the rainy season, the soil layer in the

cropping plots has been eroded out, so the soil profile was changed. The top of soil layer in the cropping plots corresponded to the level of 2–3 cm in depth of the original soil profile.

In 1979, maximum and minimum temperature varied from 26.5 (November) to 32.8°C (March) and 14.4 (November) to 21.6°C (June) respectively. Annual rain fall average was 1532.1 mm for a mean of recent 5 years with yearly variation from 1145 mm, in 1973 to 1955 mm in 1977. Air temperature was relatively stable through a year. In contrast to the temperature, rainfall showed a clear seasonal pattern with the dry season generally lasting from November to February and the rainy season of more than 7 months. During the rainy season, the distribution of rain showed a bimodal pattern having two peaks in April–May and September respectively.

Sampling and Extraction Methods

According to the habitats utilization, soil microarthropods are divided into two groups, i.e. surface dwelling and soil dwelling species. Two methods were used for the collection of soil microarthropods, i.e. Tullgren funnel for soil arthropods and pit fall trap method for the collection of surface dwelling form species.

Pit fall trap method was used for the estimation of soil animal's activities and for a tentative estimation of the abundance of surface dwelling species. Plastic cups of each 200 cm^2 in surface area and 4 cm in depth were used for pit fall trap. These traps were placed in the ground such that the lit of the traps was leveled with soil surface and covered with leaf litter. A saturated picric acid was used for the preservative solution. Ten pit traps were set at 1 meter intervals in the forest and cropping plots. Trapping period was 3 days and the animals collected were identified under a stereo-binocular microscope.

Population densities of soil animals were estimated by taking soil samples. Soil cores of each 25 cm^2 in surface area and 8 cm in depth were taken by using cylindric sampler. The soil cores collected were divided into two layers of each 4 cm in thickness. For the study of vertical distribution of Collembola, sampling was made on three occasions, before and after the burning and in the rainy season. Samples consists of 10 soil cores being each 25 cm^2 in area and 8 cm in depth for the samples before and after the burning and 12 cm for the samples of rainy season. Then, total 40 samples were collected. The soil cores were divided into the layers of each 2 cm in thickness. Soil animals were extracted by Tullgren funnel exractor at constant temperature of 40°C (temperature in cabinet). The period of extraction depended upon the soil water contents of samples and varied 2–5 days. The extracted animals were collected into a alcohol solution of 95%. The identification, counting, and measurement were undertaken under a binocular microscope with a micrometer.

Results

Seasonal Changes in Soil Temperature and Water contents

Soil water content of 0–5 and 5–10 cm in depth of soil layer was measured on each sampling occasion and was expressed as a percentage of water to dry weight of soil. Soil temperature was measured at 5 cm in depth. Soil water tension was measured for the soil samples of 0–10 cm layer collected before the burning in the cropping plot.

The results of seasonal changes in soil temperature and water contents are shown in Fig.

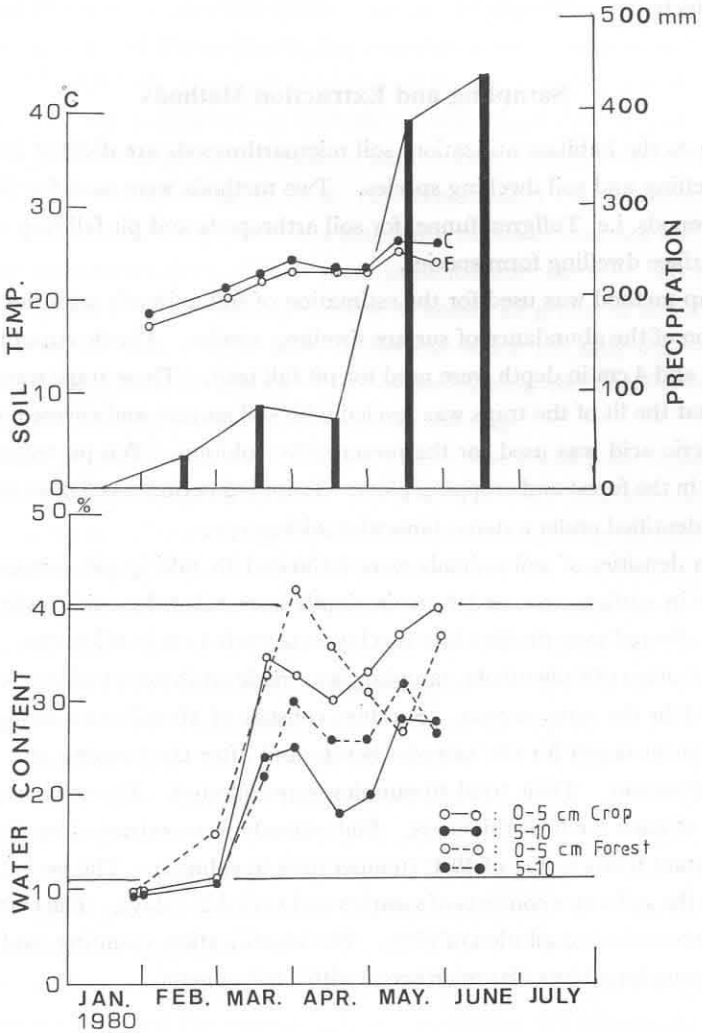

Fig. 1. Seasonal changes in the water content of soil (0–5 and 5–10 cm) and soil temperature at 5 cm deep during the study period. Seasonal changes in air temperature and precipitation at the Nam Phrom study area.

1. The results showed that 45% of soil water content was corresponded to the field capacity and 11% for the wilting point of plants. Water content of soil was neartly at the wilting point during the dry season and suddenly increased to the field capacity by the onset of rain in April. During the rainy season, the water contents showed variations around 40 and 35% in the cropping and the forest plot respectively. The low water content in the cropping plot was due to the low water holding capacity of the soil. While the soil temperature was relatively constant through the study period and ranged from 24 to 30°C in 5 cm in soil depth.

Activities of Surface Dwelling Species

The arthropods trapped were classified into order for Insect and class for the other arthropods. The faunal compositions are shown in Table 1. The numbers of total arthropods, Collembola and Acari trapped are shown in Fig. 2.

There was no significant difference between the numbers of each animal group trapped before and after the burning. Before the burning, Collembola was predominant and accounted for 24% of the total arthropods. After the burning, the dominance was changed to

Table 1. Faunal composition of surface dwelling animal groups. The means are expressed as numbers trapped per one trap during 3 days.

Animal group	Forest	Crop	Forest	Crop
	(13–16. January 1980)		(28–31 May 1980)	
Insecta	mean standerd errors			
1. Collembola	2.65±0.63	2.22±0.55	23.87±3.78	13.43±0.86
2. Orthoptera	0.44±0.24		0.75±0.41	1.30±0.57
3. Blattaria	0.33±0.24	0.22±0.15	0.25±0.16	
4. Isoptera	0.77±0.46			
5. Lepidoptera (larvae)	0.22±0.15	0.44±0.44	0.25±0.16	0.43±0.20
6. Diptera (adult)	0.67±0.29		0.37±0.26	0.86±0.46
7. (larvae)	0.22±0.15		0.50±0.19	2.85±0.82
8. Coleoptera (adult)	1.22±0.32	1.33±0.55	0.88±0.40	0.85±0.55
9. (larvae)	0.22±0.15	0.44±0.44		0.13±0.12
10. Homoptera	0.22±0.15	0.22±0.22	0.13±0.13	0.43±0.20
11. Hemiptera	0.22±0.15			
12. Hymenoptera (Formicidae)	1.67±0.65	1.67±0.85	11.38±6.15	21.40±14.50
Other arthropods				
13. Pseudoscorpiones	0.22±0.15			
14. Acarina	1.78±0.86	10.44±3.44	14.43±1.98	11.29±2.77
15. Araneida	1.11±0.95	0.44±0.24	1.53±0.38	
16. Opiliones			0.38±0.26	
17. Isopoda			0.13±0.12	
18. Diplopoda			0.13±0.12	0.13±0.12
Total arthropods	11.87±1.84	17.42±3.95	56.05±4.62	54.59±15.12

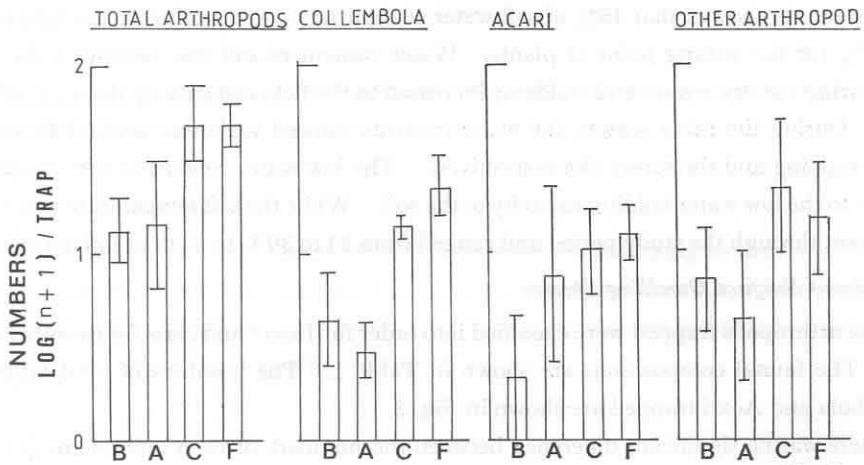

Fig. 2. Comparison of the population density of surface dwelling species trapped by the pit-fall trap method.
B: Before the burning, A: After the burning, C: the cropping plot, and F: the forest plot.
The numbers expressed by log(n+1) where n is the numbers trapped per trap.

Acari, which accounted for 59% of the total individuals of soil arthropods.

In the rainy season, the total arthropods, Collembola and Acari increased in number in both plots. But there was no significant difference in numbers between the forest and cropping plots. The burning and cutting of forest resulted in a reduction in number of animal groups as shown in Table 1. But there was no significant difference in number of individuals between the plots.

Population Density of Soil Arthropods

The soil arthropods collected during the study period were classified into three groups i.e. Acari, Collembola and the other arthropods. Population densities of each group are shown in Table 2 with standard errors.

In both plots, Acari was predominant among the soil animals and accounted for 70 and

Table 2. Mean density of each animal groups in the cropping and forest plots. Density is expressed by numbers per 1 M^2.

Group	Forest plot	Cropping plot	
	mean standard errors	mean standard errors	
Collembola	3810±1066	960± 253	significant ($P<0.05$)
Acari	11223±2855	5356±1075	n.s.
other arthropods	1089± 285	1940± 450	n.s.
total arthropods	16122±5159	8253±2950	n.s.

64% of the total arthropods in the forest and the cropping plots respectively. There was no significant difference in numbers between the plots, although population was about two times higher in the forest than in the cropping plots. Collembola was second in abundance and accounted for 23% and 12% of total arthropods in the forest and the cropping plot respectively. Collembolan population was four times abundant in the forest than in the cropping plot and this difference was significant at $P<0.05$ level. For the other arthropods there was no significant difference in numbers between the plots.

Seasonal Changes in Number of Collembola and Acari

Seasonal changes in number of Collembola and Acari are shown in Fig. 3.

Similarity of seasonal trend in number of Collembola between the plots was examined by the Sperman's rank correlation (SIEGEL 1960). Two trends were significantly correlated ($P<0.05$). In both plots, the seasonal trend in number of Collembola showed a similar pattern. While the mean density was higher in the forest than in the cropping plots. Collembola population showed a decrease in number through the dry season and then followed a sudden increase in number in April when the soil condition became to wet by the onset of the rainy season. During the rainy season, populations were relatively stable, although there were some variations in numbers.

Seasonal trend in number of Acari was different between the plots. In the forest plot, population decreased during the dry season and then begin to increase at the onset of the

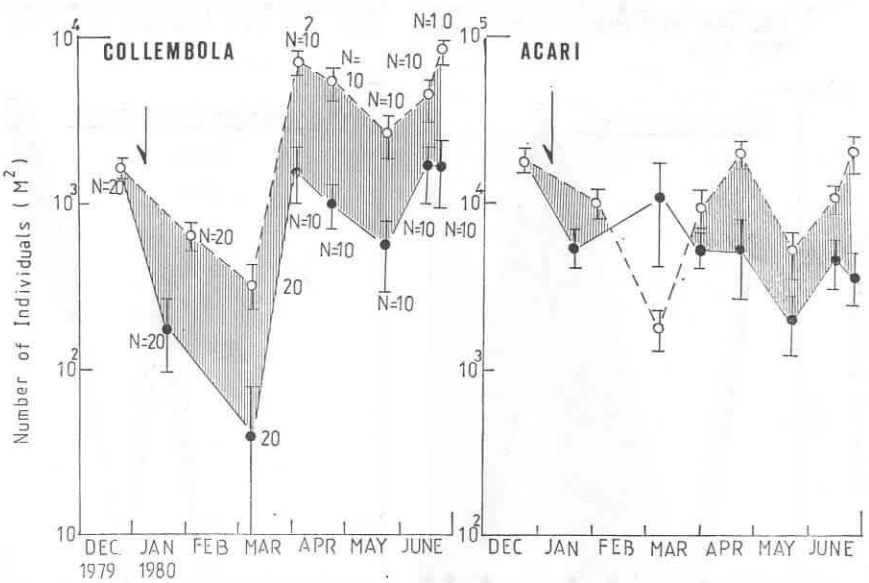

Fig. 3. Seasonal changes in number of Collembola and Acari in the cropping and the forest plots. (○) and (●) indicate the populations in the forest and cropping plots respectively. *N* indicates the number of soil cores taken in each sampling date. Bars indicate the standard errors. Arrows indicate the timing of burning.

rainy season. During the rainy season, population showed variations in numbers. This seasonal trend was similar to that of collembola. In the cropping plot, population showed

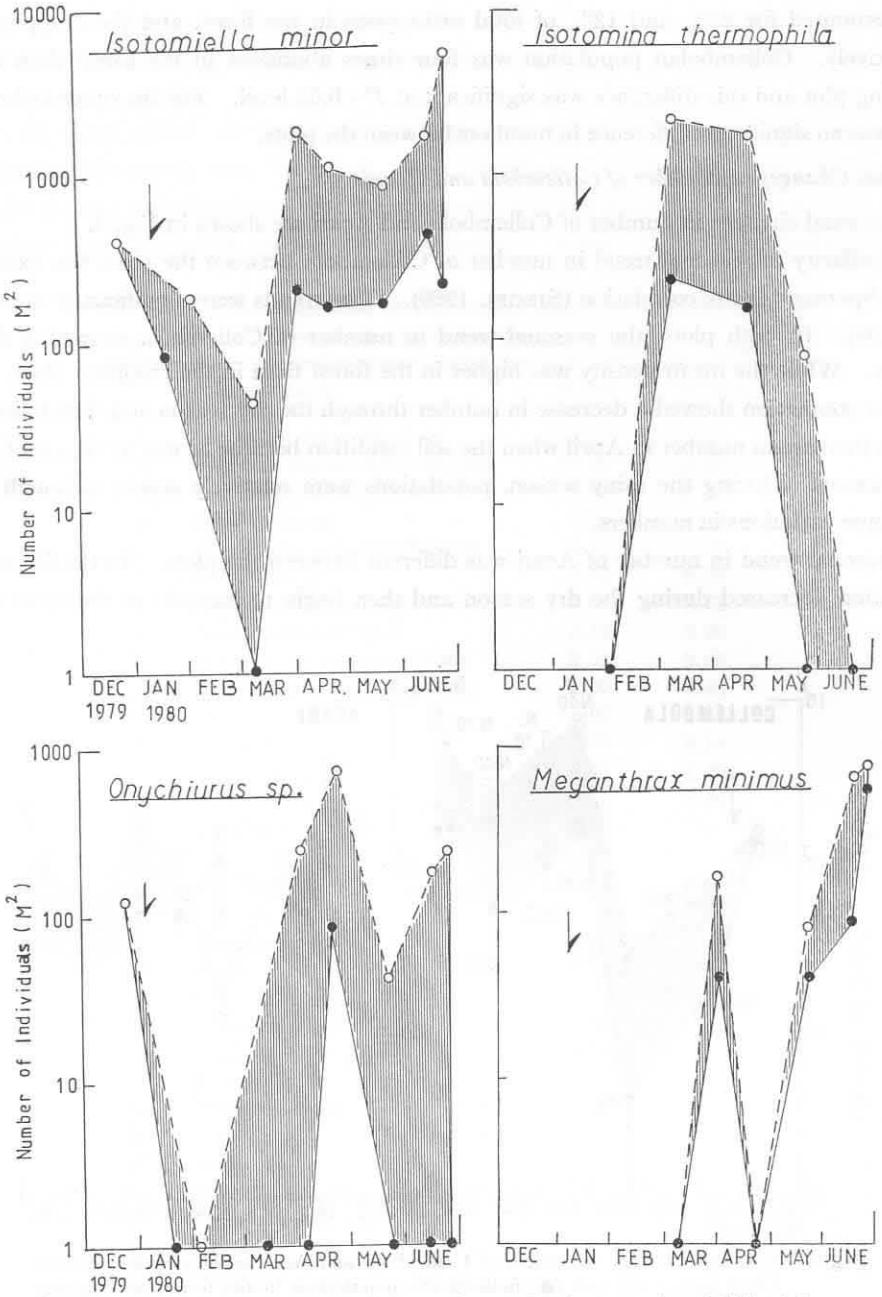

Fig. 4. Seasonal changes in numbers of some dominant species of Collembola. Arrows indicate the timing of burning.

a decrease in number after the burning and then increased in number at the end of dry season. This increase was due to an out-break of one species of Acari. During the rainy season, population was decreased in number through the study period until the end of June as the decreases of the outbreak species.

Seasonal Changes in Number of Some Dominant Species of Collembolsa

Seasonal changes in number of some dominant species of Collembola are shown in Fig. 4. In every species, it was apparent that population density was lower in the cropping plots than in the forest plot. All the species examined showed a synchronous increase in number at the onset of the rainy season. For the two species. *Istomiella minor* and *Isotomina thermophila*, seasonal changes in number were examined together with those in body length distribution. *I. minor* was a dominant species and accounted for 56% of the total collembola. Seasonal changes in number of this species were compared with those of the collembola as a whole using the rank correlation and there was a significant similarity between the seasonal patterns ($P<0.05$). The size distribution consisted of the overlapped generations and this suggests the multivoltine life cycle of this species. In the case of *I. thermophila* the individuals appeared in May consisted of newly hatched juveniles and then growed into adults stage until the end of May. This life cycle pattern resulted in the unimodal seasonal pattern in number with a peak at the appearence of juveniles in April.

Vertical Distribution of Collembola

Vertical distribution of Collembola was studied on three occasions in the cropping and

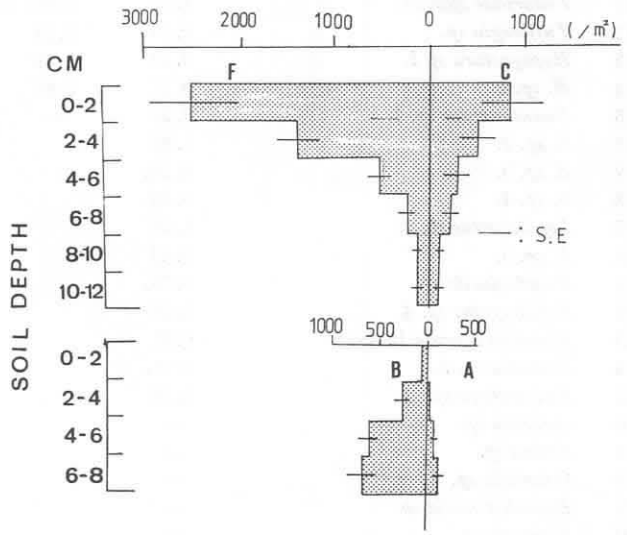

Fig. 5. Vertical distribution of Collembola. The numbers of Collembola in each soil layer is expressed as a density per 1 m². B; before the burning, A; after the burning, F; the forest, C; the cropping plot. Bars indicate the standard errors.

the forest plots (Fig. 5). Before the burning, Collembola as a whole had its modes of distribution at the deeper layers at about 4–8 cm in depth. After the burning, the vertical distribution was changed through the elimination of individuals from the surface layer and the population decrease in the deeper layers. The burning had thus an overall effect on the populations through the mortality being especially intense for the individuals in the surface layers.

In the rainy season, the realtionship of population and depth reversed and the number of individuals decreased with the depth. The changes in vertical distribution between the rainy and the dry season indicate that the colonization of individuals from the deeper layer to the surface layer took place during the rainy season. A comparison of the vertical distri-

Table 3. Species composition of Collembolan communities in the cropping and the forest plot during the sampling period.

	Species name	Forest	Cropping
1	*Isotomiella minor* SHAFFER	41.02	21.95
2	*Isotomina thermophila* AXELSON	13.96	6.53
3	*Folsomides purvus* FOLSOM	6.70	12.27
4	*Lepidocyrtus sp.*	5.21	4.43
5	*Meganthrax minimus* WILLEM	5.74	11.80
6	*Onychiurus sp.*	5.43	6.72
7	*Microparonella ceylonica* YOSII	2.87	2.52
8	*Sinella hofti* SHÄFFER	2.16	3.90
9	*Folsomina onychiurina* DENIS	2.01	8.60
10	*Dicranocentrus indicus* BONET	2.00	9.86
11	*Poduridae sp.*	1.07	2.06
12	*Tullbergia sp.*	0.59	8.14
13	*Hypogastura sp 1.*	0.42	1.49
14	*H. sp. 2.*	0.22	0.80
15	*Sminthuridae sp. 1.*	3.37	—
16	*S. sp. 2.*	1.91	
17	*S. sp. 3.*	0.50.	
18	*S. sp. 4.*	0.25	
19	*Lepidocyrtus sp. 2.*	1.09	
20	*L. sp. 3.*	0.42	
21	*Pseudosinella sp.*	0.70.	
22	*Lepidocyrtus sp. 4.*	0.56	
23	*Homidia cingula* BÖRNER	0.31	
24	*Homidia sp. 2.*	0.01.	
25	*Entomobrya sp.*	0.39	
26	*Anurida sp.*	—	
27	*Salina sp.*	—	
28	*Odontella sp.*	—	
29	*Branchstomella sp.*	—	
30	*Neanura sp.*	—	
31.	*Willowsia sp.*	—	
		100(%)	100(%).

butions in the forest and the cropping plots showed that population density in the upper two layers was significantly higher in the forest than in the cropping plot. The low abundance of population in the upper two layers in the cropping plot accounted for the differences in population density between the plots.

Community Structure of Collembola

The species compositions are shown in Table 3. The mean body length of individuals in the forest and the cropping plot were 0.55 mm and 0.52 mm respectively and there was no significant difference between the body lengths. The relative abundance of species in each plot was shown in Fig. 6. The relative abundance of the common 15 species was compared between the communities by ranking the species sequence. The species sequences were significantly correlated ($P<0.05$). The results suggest that the collembolan community

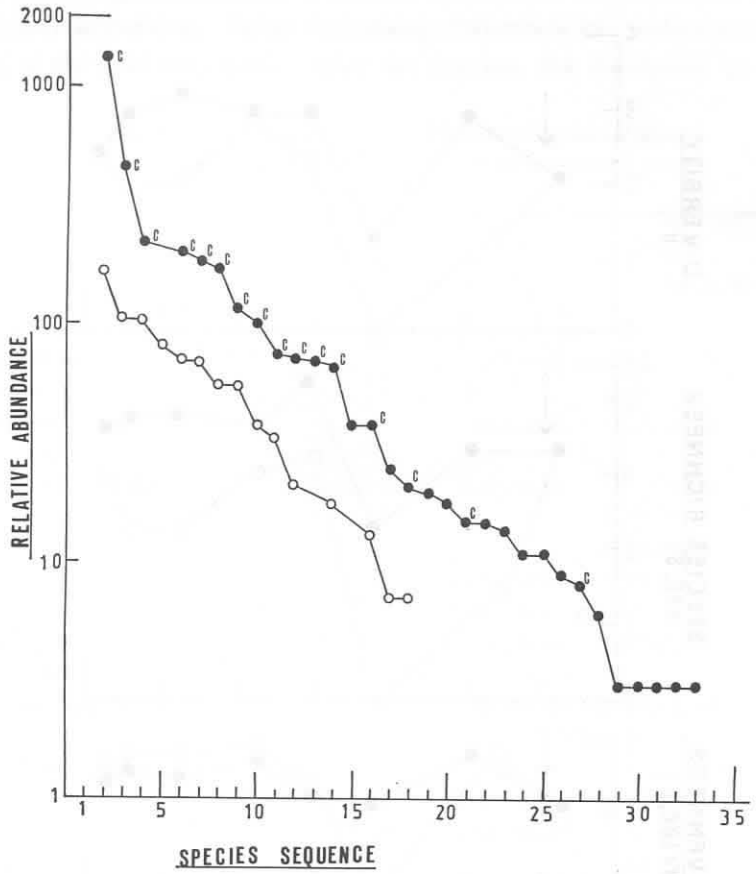

Fig. 6. Patterns of relative abundance of Colembolan species in the plots during sampling period. For each species, relative abundance is plotted against rank, ordered from most to least abundant. (●) and (○) indicate the forest and the cropping plots respectively. C indicates the common species to both plots.

of the cropping plot represents a part of the forest community rather than a different type of community in species composition.

To evaluate the community structure, some indices were calculated, diversity from Shannon formula;

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i \qquad (1)$$

where p_i is the proporation of total number of individuals belonging to the i species and s is the total number of species. Diversity consists of two components i. *e*, species richness and evenness or relative abundance of species. The evenness (J') was estimated by the following formula where $\log_2 S$ is the species richness.

$$J' = \frac{H'}{\log_2 S}, \qquad (2)$$

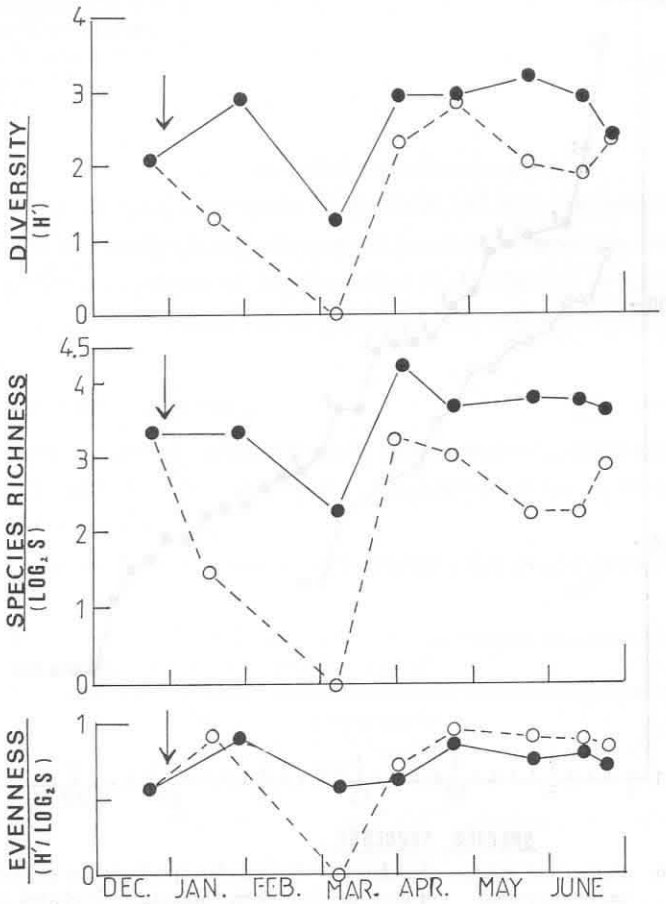

Fig. 7. Seasonal changes in diversity, species richness, and evenness. Arrows indicate the burning of the forest. (●) and (○) indicate the forest and the cropping plot respectively.

The seasonal changes in diversity, species richness, and eveness were shown in Fig. 7. The evenness was slightly higher in the cropping plot than in the forest plot. The species richness was significantly higher in the forest than in the cropping plot. The increase in evenness in the cropping plot was counter balanced by the decrease of species richness in the forest plots and the diversity was thus not so different between the plots.

Discussion

Population densities of soil microarthropods are generally lower in the tropical than in the temperate forest soils (WALLWORK 1976, and SWIFT et al. 1980). Among the soil-microarthropods, Collembola and Acari are usually dominant in the both forest soils. In this study area Acari and Collembola were dominant and accounted for 76% and 93% of total microarthropods in the cropping and the forest plot respectively.

Population densities of Collembola have been studied in the various tropical forests and were 3217 per 1 m^2 in central Thailand (OGINO et al. 1965), 4193 per 1 m^2 in savana in Lamoto, West Africa (ATHIAS 1975), 6320-7937 per 1 m^2 in Nigerian rain forest (LASEBIKAN 1975), 17648 per 1 m^2 in Nigerian bush (CHRITCHLEY et al. 1979) and 12321–21975 per 1 m^2 in Congo rain forest (MALDAGUE & HILGER 1963). Population densities of Collembola were 3810 and 960 per 1 m^2 in the forest and the cropping plot respectively and these were comparable to the population densities estimated in the other tropical forest soils. These population densities estimated in the tropical forest soils are apparently lower than those in the temperate forest soils where Collembola usually range 10,000 to 100,000 per 1 m^2 (HALE 1967).

There are probably two primary reasons to explaine the low abundance of Collembola in the tropical forest soils. Accumulation of organic matter is rather lower in the tropical than in the temperate forest soils (RICHARD 1952, and TSUTSUMI 1967, 1973). Collembola usually live in the litter and the top of the soil profile (e.g. HALALφV 1960 and TAKEDA 1978), and the abundances in a given habitat are related to the amounts of A_0 and organic matter (DHILLON et al. 1972, GILL 1969 and TAKEDA 1979). Thus the low accumulation of soil organic matter in the tropical forest should be correlated to a degree with Collembolan abundance.

Further, the sharply defined wet and dry seasons are typical climate in some tropical forests such as the monsoon forest. The drought conditions may develop in the upper layer of the soil profile as the advance of dry season. The dry season is thus a critical period for the survival of Collembolan populations, since Collembola is vulnerable to low moisture conditions (CHRISTIANSEN 1964). In this study area, Collembolan populations showed a well marked seasonal trend. Collembolan populations showed a decline in numbers and a concentration of individuals in the deeper soil layer as the advance of dry season. The vertical ditribution of Collembola in the dry season may be explained by the vertical different

mortality and the downward migration. The downward migration of Collembola have been observed in the adverse wether conditions, such as drought conditions (TAKEDA 1978) and may contribute to the survival of Collembolan populations as a mean of adaptations to escape the dry conditions. Of the Collembolan communities in this study area, the smaller sized species such as, *Isotomiella minor*, *Folsomides purvus* were dominant and the mean body length of total Collembola was 0.52 mm and 0.55 mm in the cropping and in the forest plot respectively. These body length seems to be smaller than those in the temperate forest soils where these range 0.65 to 0.91 mm. (TAKEDA, unpublished). In the tropical forest where drought conditions are the rule rather than the exception during the dry season, this climatical conditions reflect on the abundance and the species composition of Collembola.

The burning of forest affects directly the microarthropods populations by increasing the mortality and this direct effect appeares as a reduction of population densities after the burning. In this study, the populations of Collembola and Acari showed a decline in numbers after the burning. The immediate decreases of population after the burning have been demonstrated in the other localities. Metz et al. (1973) compared the population of mesofauna before and after an annual summer fire in a pine forest in North America and showed that the mesofauna was reduced to about 45% of these present before the fire. HUHTA et al. (1967) found that the direct effect was very destructive to nearly all group of soil animals and was especially intensive for Lumbricidae and Collembola which left only 6% of initial density. The direct effect is caused by the heat produced by the burning and thus the degree of destruction of soil animals dependent on the intensity of the burning.

The changes in the soil that follow the burning of forest affect the recovering process of the populations through the reduction of living space and the modification of soil environments. The burning effects on soil animals have been studied by comparing the population densities between the burnt area and unburnt area. In the pampa, De Izarra (1977) compared the populations of mesofaunas between the burnt and the protected area for the fire and showed that the burning had no effect on the population density because of the low intensity of burning accounted by the low accumulations of the organic matter. HUHTA et al. (1969) showed that the burning of forest caused a transitory increase in density of Collembola followed by a decline to subnormal population level after 4 years and recovery to abonormally high level 7 years later. In contrast to these studies, ATHIAS (1975) showed that microarthropods in savana in West Africa showed the population decreases in the burnt area compared with that of the protected area. The results obtained by the works of burning on mesofauna often differ widely, depending on the conditions of soil and vegetation where the studies carried out and even on the intensity of burning.

In this study the mean population density of Collembols was lower in the cropping plots than in the forest plot. But the seasonal changes in number of Collembola showed a similar pattern between the plots. These results suggest that the burning had no effects on the seasonal trends of Collembola. A comparison of the vertical distribution of Collembola between

the plots indicated that a significant population decrease in the upper soil layers was apparent in the cropping plot. The A_0 and part of A layer were lost by the burning and the erosion followed by the onset of rainy season. The reduction of habitat thus accounted for the population decreases in the cropping plot. HILL et al. (1975) have reviewed the works of effect of forest fire on measofauna and concluded that the extent of their effects dependes upon both the intensity of the fire and susceptibility of the site to erosion. This view is applicable to the present results in Nam Prom study area where is susceptible to erosion after the burning because of the lost of A_0 and part of A layer. The changes in population abundance and cummunity were accounted for by the reduction of habitas. The present results suggest that the recovering of abundance and community of Collembola should be related to that of the soil conditions, especially the soil structures as habitats.

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